

METALLIC AND ANTIOXIDANT ENZYMES COMPOSITION OF THE BONES AND MUSCLES OF SOME COMMERCIAL FISH SPECIES IN OJO LAGOON, LAGOS

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ABSTRACT

This study investigated the metallic composition of Zinc (Zn), Copper (Cu), Phosphorus (P), Manganese (Mn), Lead (Pb), Iron (Fe), and Magnesium (Mg) and antioxidant enzymes [Super Oxide Dismutase (SOD), Catalase (CAT), Glutathionine (GSH) and Malonaldehyde (MDA)] activities in the bones and muscles of four freshwater fish species sourced from fish mongers in Ojo Lagoon landing site, Lagos State. The fishes (*Coptodon zillii*, *Heterobranchus bidorsalis*, *Clarias gariepinus* and *Chrysichthys nigrodigitatus*) were stored on ice at 4°C and analyzed at the Biochemistry and Pharmaceutical Laboratory Section of the College of Medicine University of Lagos, Idi-Araba, Lagos, Nigeria. Heavy metals were analyzed using Atomic Absorption spectroscopy (AAS), while antioxidant enzyme activities was determined using the supernatant (20%) and a specified hydrogen peroxide volume with a catalase inhibitor. Results showed significant difference ($P < 0.05$) among metals and antioxidants in all studied fish samples except for SOD activity in their muscles. The order of metallic concentrations in the fish tissues was $Fe > Mn > Mg > P > Pb > Cu > Zn$, with Mg, Pb, and Mn concentrations recorded higher than the permissible limits for consumption as recommended by standard organization such as FAO, FEPA and WHO. *C. zillii* muscle recorded the highest values of SOD and GSH, and the muscles of *C. nigrodigitatus* and *C. gariepinus* were highest in CAT and MDA respectively. The bone of *C. nigrodigitatus* had the highest GSH, CAT, and MDA activities and *C. zillii* recorded the highest SOD activity. The study concluded that the fish were nutritionally unhealthy and unsafe for human consumption and, as such not recommended for inclusion in the diet.

Keywords: Metal composition, antioxidants, fish, health, nutrition.

INTRODUCTION

The continuous unregulated waste disposal coupled with the lack of effective management of water, especially in developing countries like Nigeria, has led to an increased decline in many water bodies (Edokpayi *et al.*, 2017). Of the constituents of these discharges or wastes, metals represent a larger portion and are, as such, considered a major threat all over the world owing to their toxicity, intrinsic persistence, non-biodegradable nature, and accumulative property (Harindintwali *et al.*, 2020). Some of these heavy metals are naturally abundant in nature and when their concentrations in the environment are above the regulatory body's threshold limits due human interventions, this could constitutes harmful substances in the environment (Amira *et al.*, 2013). Fish are one of the most frequent bio-indicators for contaminants since they are found at higher trophic levels in the food chain (Ali and Khan, 2018). Fish is unarguably the major source of protein consumed by humans for many

years (Toso *et al.*, 2021); thus, the human body is largely susceptible to increased heavy metal concentrations in fish (Tolian *et al.*, 2020). Consequently, an analysis of the abundance of heavy metals in fish could be used to determine the impacts of human activities on ecosystems and human health. Fish may bio-accumulate heavy metals in their tissues and are, therefore, used as heavy metal bio-indicators of the aquatic environments in which they live and feed (Authman *et al.*, 2015). The pollution from heavy metals has been reported to also induce behavioral, biochemical, and molecular alterations in aquatic organisms through the production of reactive oxygen species (ROS) that lead to oxidative stress and carcinogenesis (Monteiro *et al.*, 2021; Jijie *et al.*, 2020). The metal toxicity in fish manifests in the form of growth deceleration, weakened immunity, histopathological changes in visceral organs, and high mortality (Abdel-Tawwab *et al.*, 2015; Authman *et al.*, 2015).

The fact that heavy metals cannot be destroyed through biological degradation and have the ability to accumulate in the environment makes these toxicants deleterious to the aquatic environment and consequently to humans who depend on aquatic animals. As a result, tissue concentrations of heavy metals can be of public health concern to both animals and humans.

Antioxidants are compounds capable of either delaying or inhibiting the oxidation processes that occur under the influence of atmospheric oxygen or reactive oxygen species (ROS) (Liu *et al.*, 2020). They are used for the stabilization of polymeric products, petrochemicals, foodstuffs, cosmetics, and pharmaceuticals, including heavy metals (Maraveas *et al.*, 2021). Antioxidants are involved in the defense mechanism of the organism against the pathologies associated with the attack of free radicals (Pasupathi *et al.*, 2008). The role of antioxidants in nutrition is an area of increasing interest (Gulcin, 2020). Antioxidants are used to prolong the shelf life and maintain the nutritional quality of lipid-containing foods such as fish and fish products and to modulate the consequences of oxidative damage in the human body (Halliwell *et al.*, 1995; Hudson 2012). This study therefore aimed at assessing the composition of metals Zinc (Zn), Copper (Cu), Phosphorus (P), Manganese (Mn), Lead (Pb), Iron (Fe), and Magnesium (Mg) and antioxidant enzymes [Super Oxide Dismutase (SOD), Catalase (CAT), Glutathionine (GSH) and Malanoaldehyde (MDA)] levels in the bones and muscles of adult *Coptodon zillii*, *Heterobranchus bidorsalis*, *Clarias gariepinus* and *Chrysichthys nigrodigitatus* obtained from Ojo Lagoon, Lagos State and popularly consumed by many Nigerians in the area.

MATERIALS AND METHODS

Sampling site

Ojo local government is located between Badagry and Amuwo-Odofin Local government Areas in Lagos, Nigeria. The creek is an extension of Badagry Creek and is situated on the Eastern section of the Trans-West African Coastal Highway, about 37 kilometers west of Lagos. It is coordinated at 60°28'N30°11'E, showing latitude 40°55'N, latitude 40°17'N, and longitudes 120°55'E and 130°E. The purpose of choosing this site was due to the large waste disposal it receives from the growing population of the town, estimated at about 2 million inhabitants. Another reason was attributed to the evolution of industries such as Doyin groups of companies that is about located about 28km to the sampling site which contributes to the waste discharged into the Lagoon.

Sample collection

Ten specimens each of four different fish species namely *C. gariepinus*, *C. zillii*, *H. bidorsalis*, and *C. nigrodigitatus* were procured from the landing site (Ojo market) early in the morning between 6:00hrs and 6:30hrs, and transported on ice to the laboratory for the extraction of the fish muscle and bone for metal and antioxidant analyses. The laboratory procedure was done at the Biochemistry Department of the Lagos University Teaching Hospital (LUTH), Idi-Araba, Lagos, Nigeria. These specimens of muscles and bone were removed, tagged and kept in a small container for further studies.

Mineral analysis

Concentrations of the metals (Na, K, Ca, Mg, Fe, Zn, Cu, P, Pb and Mn) were determined in the isolated bone and muscle of the four species using Atomic Absorption spectrophotometer (AAS) with the adoption of Perkin's Elmer Spectrophotometry (USA model 205 series). All determinations were done in replicated for both the muscles and bone tissues collected.

Antioxidant analysis

Samples from the muscle and bone tissues were homogenized in 2.5 ml of cold-specific buffer saline for each antioxidant biomarker using a Potter-Elvehjem glass/Teflon homogenizer. For about 10 minutes at 40 °C, the homogenates were centrifuged at 1600 rpm, giving rise to supernatants stored at -200 °C before analysis. SOD activity was determined using the supernatant (20%) according to the method described by Nishikimi *et al.* (1972). The activities of CAT enzymes was estimated based on terminating the reaction between CAT and the specified hydrogen peroxide volume with a catalase inhibitor as described by Aebi, (1984). GSH activities was obtained using Paglia and Valentine (1967) while MDA level was assessed using the procedure of Mihara and Uchiyama, (1978).

Statistical analysis

All data were presented as mean SE. The raw data were normally distributed, as determined by Kolmogorov-Smirnov tests. The homogeneity of variances among the sample was assessed using Bartlett's test. Differences between the means were tested at the 5% probability level using Duncan's test after statistically analyzing the data with the ANOVA test. The statistical analysis was conducted using Statistical Processor System Support (SPSS) software, version 25.0, IBM, Chicago, USA.

RESULTS

The heavy metals compositions in the muscles and bones of the sampled fish are presented in Tables 1 and 2 respectively. There was no significant difference observed in the Zn of both the muscles

and bones of the four species. Zn contents of the muscles and bones ranged from 1.08 ± 0.17 in *C. gariepinus* to 1.21 ± 0.03 in *C. zillii* and from 1.10 ± 0.08 in *H. bidorsalis* to 1.32 ± 0.04 in *C. nigrodigitatus* respectively. *C. zillii* recorded the highest Cu (3.48 ± 0.06) and P (6.74 ± 0.23) concentrations in the muscles while *H. bidorsalis* (2.61 ± 0.32) and *C. gariepinus* (6.20 ± 0.09) had the least values for Cu and P respectively. Conversely, the bone tissue recorded the highest Cu and P contents in *H. bidorsalis* while *C. nigrodigitatus* and *C. zillii* showed the least values in Cu and P respectively. Similar to the muscles of the sampled fish which recorded significant differences of Mn ranged from 32.70 ± 0.36 in *H. bidorsalis*, 32.70 ± 0.38 in *C. nigrodigitatus* to 35.20 ± 0.29 in *C. gariepinus*. The bone also recorded significant differences ($p < 0.05$) among the fish samples with *C.*

gariepinus having the highest value of 32.45 ± 0.32 and the least value of 30.62 ± 0.54 was obtained in *C. zillii*. Significant differences were also noticed in the Pb, Mg and Fe concentrations of the samples' muscles with Pb and Mg values well above the prescribed limit set by FEPA, WHO (2mg/kg for Pb) and FAO (0.05 for Mg) while Fe concentrations was within the permissible limit of 146 by IAES. Pb concentrations in the bones were highest in *C. gariepinus* (4.45 ± 0.05) and lowest in *C. zillii* (4.02 ± 0.02), exceeded the FEPA and WHO limits of 2 mg/kg. Mg levels also exceeded FAO's 0.05 mg/kg limit, with the highest concentration in *C. gariepinus* (7.67 ± 0.31) and the lowest in *C. zillii* (6.98 ± 0.04). Fe concentrations in the bones were within permissible limits, ranging from 108.02 ± 0.32 in *C. nigrodigitatus* to 117.69 ± 0.44 in *C. gariepinus*.

Table 1: Mean heavy metal concentrations in the muscle of *Coptodon zillii*, *Heterobranchus bidorsalis*, *Clarias gariepinus* and *Chrysichthys nigrodigitatus*

Metals (mg/kg)	<i>C. zillii</i>	<i>H. bidorsalis</i>	<i>C. gariepinus</i>	<i>C. nigrodigitatus</i>	Tolerance levels (mg/kg)
Zn ²⁺	1.21 ± 0.03^a	1.16 ± 0.10^a	1.08 ± 0.17^a	1.09 ± 0.15^a	7.0-7.5; 7.5 FEPA 2003; WHO 1996
Cu ²⁺	3.48 ± 0.06^a	2.61 ± 0.32^b	2.77 ± 0.07^c	2.83 ± 0.03^c	20 TFC, 2002
P	6.74 ± 0.23^a	6.53 ± 0.04^a	6.20 ± 0.09^b	6.50 ± 0.04^a	N.A
Mn ²⁺	33.74 ± 0.34^a	32.70 ± 0.36^b	35.20 ± 0.29^c	32.70 ± 0.38^b	3.52 and 0.50 IAEA-407; Wyse <i>et al.</i> , 2003; FEPA 2003
Pb	4.28 ± 0.06^a	4.70 ± 0.14^b	4.47 ± 0.06^b	4.60 ± 0.12^c	2 FEPA, 2003; WHO 1996
Mg ²⁺	7.14 ± 0.26^a	7.27 ± 0.07^a	7.37 ± 0.28^c	7.22 ± 0.27^d	0.05 - FAO 2011
Fe ²⁺	114.75 ± 0.35^a	117.85 ± 0.21^b	112.55 ± 0.49^c	117.70 ± 0.22^d	146 - IAEA-407; Wyse <i>et al.</i> , 2003

Means with similar letters in a row are statistically not-significant ($p > 0.05$)

Table 2: Mean heavy metal concentrations in the bones of *Coptodon zillii*, *Heterobranchus bidorsalis*, *Clarias gariepinus* and *Chrysichthys nigrodigitatus*

Metals (mg/kg)	<i>C. zillii</i>	<i>H. bidorsalis</i>	<i>C. gariepinus</i>	<i>C. nigrodigitatus</i>	Tolerance levels (mg/kg)
Zn ²⁺	1.20 ± 0.02^a	1.10 ± 0.08^a	1.20 ± 0.03^a	1.32 ± 0.04^b	7.0-7.5; 7.5 FEPA, 2003; WHO 1996
Cu ²⁺	2.95 ± 0.08^a	3.11 ± 0.06^b	2.75 ± 0.07^a	2.23 ± 0.03^c	20 TFC, 2002
P	5.57 ± 0.06^a	6.56 ± 0.06^b	6.13 ± 0.18^c	6.45 ± 0.12^c	N.A
Mn ²⁺	30.62 ± 0.54^a	31.23 ± 0.35^b	32.45 ± 0.32^c	31.23 ± 0.37^b	3.52 and 0.50 IAEA-407, Wyse <i>et al.</i> , 2003 FEPA 2003
Pb	4.02 ± 0.02^a	4.43 ± 0.09^b	4.39 ± 0.06^c	4.45 ± 0.05^{bc}	2 FEPA 2003; WHO 1996
Mg ²⁺	6.98 ± 0.04^a	7.23 ± 0.06^b	7.67 ± 0.31^c	7.53 ± 0.02^d	0.05 FAO 2011
Fe ²⁺	112.81 ± 0.39^a	110.17 ± 0.40^b	117.69 ± 0.44^c	108.02 ± 0.32^d	146 IAEA-407, Wyse <i>et al.</i> , 2003

Means with similar letters in a row are statistically not-significant (P>0.05).

The antioxidant biomarkers in the muscles and bones of the sampled fish species are presented in Tables 3 and 4 respectively. GSH levels in the muscle ranged from 21.77±0.95 in *C. gariepinus* to 23.43±1.19 in *C. zillii*, while the bones recorded GSH level ranging from 21.93±1.58 in *H. bidorsalis* to 23.91±0.13 in *C. nigrodigitatus*. No significant difference (P>0.05) was observed in SOD levels of both tissues, with *C. zillii* having the highest values of 3.17±0.26 and 3.08±0.09 in the muscles and bones respectively. Significant

difference (P<0.05) was observed in the CAT levels ranges from 0.40±0.03 in *H. bidorsalis* to 1.71±0.06 in *C. nigrodigitatus* and from 0.42±0.07 in *H. bidorsalis* to 0.71±0.04 in *C. nigrodigitatus*, in the muscles and bones respectively. MDA levels also varied significantly, with the lowest in *C. zillii* (1.26±0.05) muscle and the highest in *C. gariepinus* (1.98±0.02), while the bones recorded significant difference (P<0.05) in MDA levels ranges from 1.40±0.02 in *C. zillii* to 2.17±0.05 in *C. nigrodigitatus*.

Table 3: Mean composition of antioxidant biomarker in the muscles of *Coptodon zillii*, *Heterobranchus bidorsalis*, *Clarias gariepinus* and *Chrysichthys nigrodigitatus*

Antioxidants/species	<i>C. zillii</i>	<i>H. bidorsalis</i>	<i>C. gariepinus</i>	<i>C. nigrodigitatus</i>
GSH (µmol/ml)	23.43±1.19 ^a	22.72±1.90 ^{ab}	21.77±0.95 ^{bc}	22.58±0.18 ^c
SOD (µmol/ml/ min/mg pro)	3.17±0.26 ^a	2.92±0.01 ^a	2.91±0.02 ^a	2.86±0.04 ^a
CAT (µmol/ml/ min/mg pro)	0.59±0.02 ^a	0.40±0.03 ^b	1.02±0.65 ^b	1.71±0.06 ^c
MDA (µmol/ml)	1.26±0.05 ^a	1.59±0.38 ^{ab}	1.98±0.02 ^b	1.78±0.31 ^c

Means with similar letters in a row are statistically not-significant (p>0.05).

Table 4: Mean composition of antioxidant biomarker in the bones of *Coptodon zillii*, *Heterobranchus bidorsalis*, *Clarias gariepinus* and *Chrysichthys nigrodigitatus*

Antioxidants/species	<i>C. zillii</i>	<i>H. bidorsalis</i>	<i>C. gariepinus</i>	<i>C. nigrodigitatus</i>
GSH (µmol/ml)	22.48±1.03 ^a	21.93±1.58 ^{ab}	22.09±1.74 ^b	23.91±0.13 ^c
SOD (µmol/ml/ min/mg pro)	3.08±0.09 ^a	2.89±0.11 ^b	2.86±0.08 ^{bc}	2.92±0.04 ^c
CAT (µmol/ml/ min/mg pro)	0.59±0.10 ^a	0.42±0.07 ^b	0.54±0.19 ^{bc}	0.71±0.04 ^c
MDA (µmol/ml)	1.40±0.02 ^a	1.62±0.24 ^a	1.99±0.14 ^b	2.17±0.05 ^c

Means with similar letters in a row are statistically not-significant (p>0.05).

DISCUSSION

The increased anthropogenic activities as a result of increased population and industrialization pose threats to aquatic ecosystems through their effects on the optimal living conditions of aquatic life (Vardhan *et al.*, 2019). In addition to the effects of discharges on the alteration of the chemical balance of the water bodies, there could be a degradation of the physiological state of the aquatic fauna and flora as well (Bhat and Qayoom, 2021). Metals have their origins in industrial effluents,

agricultural discharges, and domestic wastes, causing a variety of harm to fish and other aquatic animals owing to their persistence and non-biodegradability (Roy *et al.*, 2021). The studied fish species namely *C. zillii*, *H. bidorsalis*, *C. gariepinus*, and *C. nigrodigitatus* were all characterized by features such as hardiness and high resistance to environmental imbalances. They have high acceptability and palatability as fish protein for human consumption. The consumption of fish contaminated with metal toxicity will lead

to a degradation of nutritional value and subsequently expose consumers to health-related issues. Therefore, knowledge of the health status of the fish to be consumed can help eradicate and reduce these risks. Sodium is the most abundant mineral in the studied species, both in bones and muscles. The high values for Na can be attributed to its important role in metabolism and physiological processes in living cells. This is in conformity with the study of Ozparlak *et al.*, (2012), who stated that high concentrations of Na, K, and Ca in fish are due to their essentiality in metabolism.

The accumulation of lead in the bones and muscles of all studied fish was above the guideline limits set by the Federal Environment Protection Agency (FEPA, 2003) and the World Health Organization (WHO, 1996). Thus, it can be suggested that the source of the fish which was Ojo Creek, and its proximity to a mega market in the area where materials such as storage batteries, cable sheaths, type metals, and solders are sold could get to the water body through surface runoff and a direct effluent discharge such as anti-knock compounds in petrol from domestic sources and the ferry terminal near the creek are causes for the high level of lead. The high values of Pb in the study were in line with the finding by Adu *et al.*, (2020), where they reported that the values of Cu, Zn, Pb, and Cr in *Ethmalosa fimbriata* in Ajegunle Creek exceeded the permissible limit. The elevated concentration of these heavy metals shows that the fish from this environment is unsafe for human consumption. Nevertheless, Heavy metal toxicity as a result of fish consumption can result in damage or reduced mental and central nervous system function, lower energy levels, and damage to blood composition, lungs, kidneys, bones, liver and other vital organs (David and Isangedighi, 2019). Also, a study showed that exposure to even low levels of Pb pollution can pose adverse effects on fish health and reproduction (Paul *et al.*, 2019), inhibit active transport mechanisms involving Adenosine triphosphate (ATP), reduce cholinesterase activities, depress the cellular oxidation-reduction reaction, and inhibit protein synthesis (Yacoub and Abdel Satar, 2003). The Zn concentration was within the regulatory limit both in the muscles and bones of all sampled fish species. This finding was in line with the study of heavy metals on *K. nana*, *C. filamentous*, and *P. lascaris* in the 3 creeks of Tomaro, Ajegunle, and Badagry in Lagos, Nigeria (Mekuleyi *et al.*, 2021). Another study by Bano *et al.* (2017) on fish organs (liver, kidney and gills) indicated high Zn concentrations in all sampled fish from farms, hatcheries, and rivers. The high values in the organs and tissues in the study of Bano *et al.*, (2017) compared to the low values obtained in bones and muscles in this study could be attributed

to the organs active and direct involvement in metal accumulation or ingestion (gill), elimination (kidney), and detoxification (liver). Fe concentrations in all sampled fish showed significant differences ($P < 0.05$) from one another. This contradicted the result of Fe concentration on three different fish species from three different creeks in Lagos as reported by Mekuleyi *et al.*, (2021), as they were not significant to one another. However, both studies reported Fe concentrations to be within the regulatory limit. Similar studies were reported by Nwani *et al.*, (2009) on Fe, Zn and Pb content in the muscles of six commercially important fish species. This study thus suggests that the Fe content in each fish will only perform its physiological responsibilities as an essential mineral for many body functions, such as binding with blood to become hemoglobin and transporting oxygen throughout the body (Briffa *et al.*, 2020), without causing any form of toxicity unless the accumulation gets increased beyond the threshold. The Mn concentration recorded was above the permissible limit. Mn toxicity is linked with a permanent neurological disorder known as manganism, with symptoms such as tremors, facial muscle spasms, and difficulty walking (Budinger *et al.*, 2021). Kuton *et al.*, (2021) reported low Mn content in electric fish (*Malapterurus electricus*) from Lekki Creek as it fell within the guideline limit. However, studies show that Mn content tends to be higher in the liver due to its ability to act as a cofactor for the initiation of a number of enzymes for metabolism (Wagner and Boman, 2003).

The toxicity limit of Ca in fish can vary depending on factors like, fish species, size, age and the environmental conditions they are exposed to. However, according to the National Research Council (NRC, 2012), the maximum tolerable level of Ca in the diet of fish is 2.5% of the dry weight of the feed. Exceeding this level can lead to a condition called hypercalcemia, which can cause various health problems such as reduced growth, kidney damage, and skeletal deformities. Exposure to heavy metal concentrations promotes reactive oxygen species (ROS) production, such as superoxide anion radicals, hydroxyl radicals, and hydrogen peroxide, through several mechanisms, such as Fenton and Haber-Weiss type reactions (Alic *et al.*, 2014). The generated ROS leads to significant mobility of antioxidant components to mitigate the harmful and toxic effects of these free radicals. Because the muscles are the edible parts eaten by consumers of fish protein, both tissues are used to assess the oxidative stress and the fish's ability to scavenge or mitigate excess ROS posed due to metal accumulation (Ogunwole *et al.*, 2021). *C. zillii* bones and muscles recorded the highest SOD activity, indicating its superiority to scavenge the effects of metal toxicity. Though all SOD

activity in the current study tends to be low, it conforms to SOD activity recorded by Parthiban and Muniyan (2011) on hepatic tissue of fish. While a study by Alengebawy *et al.*, (2021) reported high SOD activity in the gills and livers of *O. niloticus* and *C. gariepinus*, which could be a result of high exposure to metal toxicity, CAT is a complementary antioxidant to SOD, where they both work together to convert superoxide radicals to oxygen and hydrogen peroxide before finally converting to inert and harmless water molecules (Yousefi *et al.*, 2023). The CAT activity recorded in this study was lowest in *H. bidorsalis* bone and muscle, showing its decreased capability to scavenge against ROS production, which could be attributed to increased accumulation of heavy metals, which significantly decrease the CAT activity as reported by Kubrak *et al.*, (2013). The reduced GSH was activated upon a continuous increase in metal accumulation and the reduced ability of the complementary SOD and CAT antioxidants to compensate for the heavy metal increase. The highest values recorded in the bone and muscle of *C. nigrodigitatus* and *C. zillii*, respectively, shows that the fish is exposed to continuous metal toxicity. Javed *et al.*, (2016) opined that continuous and chronic exposure to metal toxicity increases the conjugation rate between metals and GSH through its thiolate sulfur atom. *Clarias gariepinus* and *C. nigrodigitatus* have the highest levels of MDA in the bone and muscle respectively, which may indicate that they are more susceptible to lipid peroxidation induced by heavy metals.

CONCLUSION

The reduced complementary SOD/CAT and MDA activities and a significantly high GSH activity recorded in the four species examined indicated that they were all capable of mitigating or scavenging the present effects of heavy metal toxicity, especially from Mn, Pb, and Mg, which were all recorded to be above the permissible limit. Thus, this study concludes that the consumption of these fish species; *C. zillii*, *C. nigrodigitatus*, *C. gariepinus*, *H. bidorsalis* are nutritionally unfit, unhealthy, and unsafe from significant health-related problems arising from metal induced pollution in the aquatic environment. Therefore, it is essential to adhere to guidelines and regulations regarding metal levels in fish to ensure food safety and public health protection. Further studies on the use of biomarkers in fish tissues and organs to efficiently assess metal toxicity at an early stage and the ecological health risk assessment associated with heavy metals in the aquatic ecosystem are recommended. Continuous monitoring of the effluent discharge into the Lagos creeks is recommended to improve the health status

of these commercially important fish species and increase their ability to reproduce and survive.

AUTHORS CONTRIBUTION:

AMH, OAB and MRA designed the study; CBD experimented and collected the data. AOA, GCS and AOI analyzed the data and wrote the draft of the manuscript. All authors approved the manuscript for submission.

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